May 5, 1994

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Enclosed is a copy of the final technical report under contract N00014-91-C-0017.

Sincerely,

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Final Report

on

ONR Contract N00014-91-C-0017

April 30, 1994

Establishing the National Polar Radio Science Consortium

The National Polar Radio Science Consortium (NPRSC) was formed during a meeting held on July 30 and 31, 1990 at the Berkeley Faculty Center on the UC Berkeley campus. The objective of the NPRCS is to represent the radio science community's interest in the HAARP (High Frequency Active Auroral Research Program) and to provide scientific advice and support to the HAARP management. The goal of this consortium is to promote participation and ensure usability of the HAARP instrument by the US radio science community.

NPRSC Member Institutions:
Boston University
Clemson University
Geospace Research, Inc
KMS Fusion, Inc
LANL
MIT
NorthWest Research Associates, Inc
Pacific-Sierra Research Corporation
Polytechnic University
Princeton University
Stanford University
UAF/GI
UC Davis
UCLA
U of Colorado
Utah State University

Objectives and Responsibilities of the NPRSC

The Geophysical Institute of the University of Alaska Fairbanks (GI-UAF) was designated as the Prime Contractor to represent the NPRSC. Since the HAARP facility will be built in Alaska, the GI-UAF can provide various logistic support activities, in addition to playing the role of coordinating the scientific advisory and support functions for the NPRSC at the request of the ONR/AFPL. These include:

1. Provide administrative support for the NPRSC activities described in the following tasks. Provide information concerning the HAARP program such as reports on scientific results from the HAARP research program, written analysis of scientific progress, and public information.
2. Provide technical and scientific advice to ONR and AFPL on such issues as the research goals of HAARP, technical and scientific requirements of HAARP, scientific merit of proposals for HAARP transmitter designs and diagnostic tools, diagnostic requirements, proposed research programs including recommendations for funding and support, and improvements to the HAARP instrument. Conduct workshops, as appropriate, to support these activities.
   Provide operational support, through such activities as on-site review of the fabrication, constructing experiments to verify performance of components during construction, validation of entire system after completion, and coordination of scheduling for research projects, using the HAARP and other diagnostic instrumentation with the HIPAS and other appropriate transmitters.
3. Provide supplemental support to NPRSC researchers to enhance the development and utilization of HAARP and its associated diagnostics.
4. Provide training of future scientists, engineers, and DOD personnel regarding HAARP related research.

The First NPRSC Workshop was held on March 26-28, 1991 at UCLA

The purpose of this workshop was to provide an opportunity for the radio science community to share in the discussion of HAARP instrument development, particularly to assess the desired HAARP transmitter/antenna system design and operating specifications. Specifically we were interested in discussing ideas, concepts, and associated physics pertinent to the following issues:

- General concepts regarding HAARP system short- and long-term basic and applied science and technology objectives;

- system design implications associated with these broad objectives;
- specific ideas and supporting physics associated with methods for enhancing ELF wave generation through electrojet modulation;
- natural or man-made limitations to implementing these strategies;
- system design implications and options for realizing these specific efficiency-enhancement methods.

The results of this workshop were summarized in a table containing the desired system parameters and performance specifications for the design of the HAARP facility. The table was submitted to the ONR/AFPL in August 1991 by the Executive Committee of the NPRSC.

The Second NPRSC Workshop was held on April 1-3, 1992 at Stanford University

The theme of this workshop was ELF/VLF Excitation and Propagation in the High-Latitude Ionosphere. The objective of the workshop was to prepare for the upcoming experimental campaign, during September 14 to October 16, 1992, at the UCLA-HIPAS Observatory in Alaska to study the ELF/VLF excitation and propagation characteristics under various conditions in the auroral ionosphere.

Campaign 92: September 14 to October 16, 1992

Campaign 92 will be conducted at the UCLA-HIPAS Laboratory in Fairbanks, Alaska. Professor Al Wong was selected to be the campaign coordinator by the Executive Committee. It has been suggested that the results of Campaign 92 should be published in a special issue of Radio Science.

Scientific issues addressed by Campaign 92 include the following.

1. Dependence of Auroral Ionosphere on Substorm Activities:
   - electron density and temperature profiles in the D- and E-regions as a function of the energy flux and spectra of precipitating auroral electrons;
   - E-field distribution as a function of substorm activities;
   - ionospheric currents as a function of substorm activities.

2. Dependence of ELF Generation on Auroral Ionospheric Conditions:

   - E-field pattern;

- D- and E-region ionization and temperature profiles;
- ionospheric Hall and Pedersen current distributions;
- field-aligned current distribution.

3. Physics of RF Heating:

- relationship between injected RF power density and altitude profile of electron temperature;
- dependence of generated ELF/VLF on RF power for O- or X-mode excitations at different frequencies.

4. Spatial Patterns of ELF/VLF Fields:
- dependence on excitation parameters;
- determination of ionospheric source characteristics.

The control center for Campaign 92 was located at the HIPAS site to which all information will be directed. A computer bulletin board was established to give latest status of operations.

NPRSC Newsletter

The first issue of the newsletter was distributed in June 1992. The second newsletter was planned to communicate the preliminary results on Campaign 92, but it never made it to the printing.

The Third NPRSC Workshop was held on April 28 to May 1 1993 at UCLA

The National Polar Radio Science Consortium organized a workshop on modification and diagnosis of the polar ionosphere. This workshop is open to the US radio science community. Results of the Campaign 92 were presented at this workshop.

A Special Session of the AGU 1993 Fall Meeting: Modifications of Ionosphere and Atmosphere by Intense HF Radio Waves

Powerful HF radio waves have been used to study the nonlinear phenomena of the ionosphere and atmosphere. Excitations of VLF, ELF and ULF waves by modulating the auroral electrojet current are research topics of current interest. Applications of high power HF radio technique to the study of ionosphere-magnetosphere coupling as well as ionosphere-atmosphere coupling are new areas of space research undergoing rapid

development. The purpose of this special session is to call the attention of the space physics community to the new results, new ideas and new opportunities in this developing area of research.

Invited speakers of the special session are

Alfred Wong
Umran S. Inan
Lewis M. Duncan
Dennis Papadoupolous
Dick Brandt